6/4/03

GLOBAL WARMING EFFECT ON CALIFORNIA HYDRO

By Maurice Roos[1]

As most of us know, very long range forecasts of global warming over the next 100 years are projecting significant climate change. Some of the more important changes could be temperature increases, possibly around 3 degrees Celsius, with a range of 1.4 to 5.8 degrees, according to the IPCC 2001 report. The increases would raise temperate zone snow levels and change the pattern of runoff from our mountain watersheds, thereby affecting reservoir operation and hydroelectric power generation. Other consequences would be sea level rise, possible larger floods and more extreme precipitation events, and changes in vegetation and the water requirements of crops and of wildlands.

Our concern today is the potential impact on hydroelectric power generation due to the anticipated snowpack changes as a result of warming. But one of the most important parameters in determining runoff and therefore water supply is precipitation. Regional precipitation predictions in the huge general circulation climate models of the atmosphere have not been reliable, in my opinion, and vary greatly among the different models.

---

[1] Presented at the California Energy Commission Hydro Power Workshop, June 5, 2003 in Sacramento.

Some models, such as the two used in the September 2000 National Water Assessment report, increase average California precipitation. Other GCMs show drier results. This is important because ultimately precipitation is the source of the "fuel", that is water, to run California's hydroelectric plants. We see it now in the yearly range of hydroelectric energy production which averages about 15 precent of the State's total demand and can be as low as 10 percent in a dry year up to perhaps 30 percent in a very wet year. So even a 5 percent change in total annual runoff would have a significant overall effect. Currently we don't know whether the future climate in northern California would be wetter or drier.

Potential Snowpack Changes

But one impact of warming is sure. Snow levels in the mountains will rise and the amount of snow covered area and the amount of water stored in the snowpack will likely decrease. A reasonable estimate is about 500 feet of elevation change for every degree C rise. Many studies have used 3 degrees C as a benchmark, which, according to the IPCC report and GCM model studies, is a reasonable mid-range 100-year projection for the western states. This would mean a rise of about 1,500 feet in average snow levels. Historical average snow elevations on April 1 (the usual peak of the snow accumulation season) range from about 4,500 feet in the north above Shasta Lake to around 6,000 feet in the southern Sierra. Earlier DWR assessments some years ago came up with estimates for a rise of 1,500 feet in the average freezing level during storms and assuming the amount of precipitation remained approximately the same. In the Sacramento River region, only about one fourth of the snow zone would remain.

The impact would be much less in the higher elevation southern Sierra. About seven tenths of the San Joaquin/Tulare Lake region snow zone would stay.

Not all the spring runoff comes from melting snow. In the northern Sierra, spring rainfall is an important contributor. The estimated average reduction in Sacramento River region April through July runoff was projected to be 43 percent, leaving 57 percent of current runoff. The southern Sierra impact was less with 23 percent reduction overall. The total runoff reduction for all watersheds was 33 percent. These results are preliminary, but have been roughly confirmed by more recent work by Scripps (Knowles and Cayan) and others.

As mentioned before, some of the GCM studies project significantly more winter season precipitation in California, some models are drier. It is possible for the southern Sierra snowpack and snowmelt runoff to increase in the wetter scenarios, albeit from less area. All models so far show less snowmelt runoff in the northern Sierra.

Less spring snowmelt would make it more difficult to refill winter reservoir flood control space during late spring and early summer of many years, thus reducing the amount of water deliverable during the dry season. Lower early summer reservoir levels also would adversely affect lake recreation and hydroelectric power production, with possible late season temperature problems for downstream fisheries.

Loss of Hydro at Foothill Reservoirs

There are essentially three elements of California hydroelectric power production: (1) run-of-the-river power plants taking advantage of unregulated or incidentally regulated river flow, (2) systems where flow is regulated by upstream power storage reservoirs where flood control is not a requirement, and (3) foothill reservoirs where power is produced more as a by-product of reservoir operations for water supply and flood control. It is difficult to say what impact climate change would have on the first group. There may be more usable water flow for hydro in some months; on the other hand, loss of snowmelt with its more even hydrograph (i.e., pattern of flow) may reduce hours of suitable flow. The effect on the second group of powerhouses, where flow is regulated by upstream power reservoirs, is likely to be small. Earlier snowmelt and some winter runoff would fill the reservoirs sooner, but the operators could hold the water until the summer high electrical load season and probably produce about the same power as now (assuming no significant changes in annual precipitation). Other utility representatives at this workshop can probably give you a better estimate of the effects of climate warming on upstream hydro project operation.

The foothill group of major multipurpose reservoirs would be expected to see the major effects. These dams account for about 2,300 MW of capacity and about 7,000 gwh of average energy production. Some early preliminary studies (Roos, 1990) at Oroville indicated a summer season energy loss of 3 to 7 percent, depending on whether operators tried to provide the same water service or reduce water releases to keep operating heads higher. This was with assumed no change in annual runoff, just the monthly pattern shift away from spring months into winter months. The basic problem is the difficulty in filling the reservoir because of reduced snowmelt runoff after winter season flood control limits are relaxed in the late spring. Because water supply is a primary purpose of all the foothill reservoirs, an analysis of the power impact at each of the twelve major multipurpose reservoir projects could be conducted. A survey of the effect on power production for average conditions should not be very complex. The impacts probably will vary greatly from one year to another, depending on the pattern and amount of runoff. It is possible, with a wetter future climate scenario, to get an increase in annual hydroelectric energy production (Yao and Georgakakos 2001).

Dr. Lund at U.C. Davis is currently adapting the economic-engineering CALVIN model for power at several CVP-SWP reservoirs; some results are expected soon.

To the author's knowledge, no systematic study has been made on the potential effect on hydroelectric power in California due to global warming. DWR's CALSIM model could be a useful tool to estimate impacts of a changed runoff pattern on major CVP and SWP reservoirs. The power routines in that model have not been used recently, but could be made operational without much work if DWR had modified river runoff scenarios developed by the academic community, which is now being planned.

My conclusion is that the potential effect of a reduced snowpack would have a substantial effect on foothill reservoir operation. The largest effect is likely to be on the Feather River basin and Lake Oroville. Based on some very prelimary studies, there would be a small reduction in hydroelectric energy and summer megawatt capacity at major multipurpose foothill reservoirs if the average annual runoff stayed the same as historical. Energy production would be more affected by a small change in wetness or dryness of the watersheds.

M.Roos:Donna Nieto
I:Roos/Hydro&Flood Ops/Roos/Global Warming Effect on California